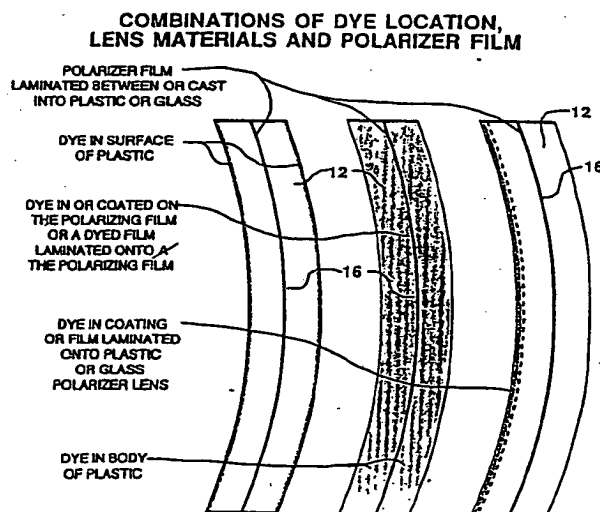




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(21) International Application Number: <b>PCT/US86/02213</b> (22) International Filing Date: <b>16 October 1986 (16.10.86)</b> (71) Applicant: <b>SUNTIGER, INCORPORATED [US/US];</b> 3043 Foothill Boulevard, Suite 12, LaCrescenta, CA 91214 (US). (72) Inventors: <b>JOHANSEN, Laurie, A. ; DIFFENDAF-</b> <b>FER, Paul, A. ; 4938 Pennsylvania Avenue, LaCres-</b> <b>centa, CA 91214 (US).</b> (74) Agent: <b>COTA, Albert, O.; 5460 White Oak Avenue,</b> <b>Suite A-331, Encino, CA 91316 (US).</b> (81) Designated States: <b>AT (European patent), AU, BE (Eu-</b> <b>ropean patent), BR, CH (European patent), DE (Eu-</b> <b>ropean patent), DK, FR (European patent), GB (Eu-</b> <b>ropean patent), IT (European patent), JP, KR, LU</b> <b>(European patent), NL (European patent), NO,</b>		SE (European patent).  <b>Published</b> <i>With international search report.</i>

(54) Title: **ULTRAVIOLET RADIATION AND BLUE LIGHT BLOCKING POLARIZING LENS**

## (57) Abstract

A lens (12) that substantially blocks horizontally polarized light and selectively blocks wavelengths between 300 and 549 nanometers. The selective blocking is controlled by a sharp cut-on filter (14) selected to cut-on at either 450, 500, 515, 530, or 550 nanometers. The specific blocking and cut-on point selected is dependent upon the ultimate usage/environment of the lens (12). If a 450 cut-on filter is selected, wavelengths between 300 and 449 nanometers are blocked before a cut-on occurs at 450 nanometers; similarly, a 550 cut-on filter blocks wavelengths between 300 and 549 nanometers before a cut-on occurs at 550 nanometers. The lens (12) also allows 30 to 40 percent of wavelengths over 625 nanometers to be transmitted. The filter (14) in combination with the polarizer (16) blocks harmful Ultraviolet radiation and blue light. While a beneficial and calming effect is achieved by wearing only blue-blocking lenses, the addition of the polarizer (16) substantially enhances the calming effect and the improvement of vision without visual discomfort.

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## ULTRAVIOLET RADIATION AND BLUE LIGHT BLOCKING POLARIZING LENS

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### TECHNICAL FIELD

The invention pertains to the general field of sunglass lenses and more particularly with lenses that combine a polarizer that blocks horizontally polarized light and a sharp cut-on filter that blocks blue light and ultraviolet radiation.

### BACKGROUND ART

15 It is well known that energy radiated in the form of light is capable of inducing and/or promoting certain photochemical reactions and that different photochemical reactions are induced by the action of light rays (or photons) of various wavelengths. Certain wavelengths of light, especially those in the blue and ultraviolet range, are known to be  
20 injurious to the eye.

Dyed lenses, when used with prescription or non-prescription sunglasses are basically intended to fulfill one of two functions: the first function is either selective or overall reduction of the injurious light and radiation. Lenses dyed for this purpose are known as protective lenses.  
25 Protective lenses may block harmful wavelengths either by reflection or, more commonly, by absorption. The second function is fulfilled by lenses which fulfill cosmetic requirements and are referred to as fashion tints. Combination dyes covering both requirements are also available.

In the current art, there are protective lenses that block blue and  
30 ultraviolet wavelengths and there are separate polarizing lenses that block horizontally polarized incident light. The combination of a polarizing and a blue and ultraviolet blocking lens is not currently available as confirmed by a listing of lenses published in 1986 by Retinitis Pigmentosa International and a search of the advertising literature. The non-availability of these combination lenses is due, in

part, to the little research that has been conducted by sunglass companies on the detrimental effect of the blue light hazard to the retina of the eye and the technical problems encountered in combining the temperature-sensitive polarizing film with the dye. This problem has  
5 been solved by the instant invention by selecting dyes that can provide the required blue blocking at a temperature that will maintain the usefulness and structural integrity of the polarizing film.

A search of the prior art did not disclose any patents that read directly on the claims of the instant invention. However, the following  
10 U.S. and foreign patents were considered related:

	<u>PATENT NO.</u>	<u>INVENTOR</u>	<u>ISSUED</u>
	4,261,656	Shy-Hsien Wu	14 April 1981
	2,307,602	Krumeich	29 August 1973
15	3,460,960	Francel et al	12 August 1969
	2,643,982	Riley	30 June 1953

The Shy-Hsien Wu patent discloses a transparent, optically clear article that consists of a glass or plastic base element that supports a thin and delicate organic or inorganic surface film such as a plastic polarizing  
20 film. The film is protected from the damaging effects of moisture, scratching and abrasion by a protective plastic coating. The hardness of the protective coating is controlled to avoid excessive flexibility or brittleness, so that good scratch resistance over a relatively soft film is obtained.

25 The Krumeich German Offenlegungsschrift discloses an optical filter that corrects red/green color blindness. The filter is designed so that in the blue to green range of the visible spectrum, the spectra curve progresses at a constant rate at very low values and increases steeply to a high value in the green to red range. The filter is particularly  
30 advantageous if its spectra curve has a permeability of under 0.01 percent in the blue to green range and a transmission that increases to approximately 100 percent in the red range.

The Francel et al. patent discloses a method of coating a vitreous substrate, such as glass, with a fluid coating composition. The coating imparts to an otherwise clear and/or transparent glass substrate the light

transmittance characteristic of amber or darker glass. The simulated amber glass obviates the necessity of having separate amber glass, batch-melting and auxiliary manufacturing apparatus and related equipment.

- 5       The Riley patent discloses an absorbent liquid coating composition that forms a film that is applied as a protective and/or decorative coating to glass and other normally transparent or translucent materials. The film has the properties of absorbing substantially all the wavelengths of ultraviolet, violet and blue light below approximately 490  
10 nanometers and substantial amounts of wavelengths from 630-750 nanometers. The film allows the transmission of selected wavelengths above 490 nanometers.

#### BRIEF DESCRIPTION OF DRAWINGS

15

FIGURE 1 is a graph that shows the five spectral curves of the invention and the position of each curve within a blocking zone, a transition zone and a transmissive zone.

20

FIGURE 2 is a graph that shows the transmission spectra of a combination of dyes that eliminate ultraviolet holes.

FIGURE 3 is a table that lists the various combination dyes, the time and temperature required to provide the specific cut-on wavelengths  
25 desired and the recommended uses for the lens.

30

FIGURE 4 is a graph that shows the failure curve of polarizers and the preferred area where a polarizer can be safely processed with the combination hot-dip dyes.

FIGURE 5 is a schematic diagram of two manufacturing processes that may be used to dye the lens.

FIGURE 6 is a cross-section of a lens showing the dye absorbed into the surface of the plastic and a polarizing film laminated between the

two halves of the cast or preformed plastic lens.

FIGURE 7 is a cross-section of a lens showing the dye in the body of the plastic and a polarizing film laminated between the two halves of the cast or preformed plastic lens.

FIGURE 8 is a cross-section of a lens having a laminated polarizing film and a dye that is in a coating or a laminated film that is bonded to the inside or outside of the lens.

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#### DISCLOSURE OF THE INVENTION

The ultraviolet radiation and blue light blocking polarizer lens is designed primarily for use with sunglasses to block horizontally polarized light, to selectively block selected wavelengths from 300 to 549 nanometers and to pass 30 to 40 percent of wavelengths longer than 625 nanometers. The selective blocking is controlled by a sharp cut-on filter selected to cut-on at either 450, 500, 515, 530, or 550 nanometers. The atmosphere blocks wavelengths that are shorter than 300 nanometers. Therefore, only wavelengths longer than 300 nanometers need be blocked for safety.

Sunglasses are normally made for light or dark conditions and it is customary to have one or two pairs of sunglasses - one for overcast days and another for sunny days. The inventive lenses found to be usable over a wide range of lighting conditions from dark rainy days to brilliant desert sun. This unexpected usefulness, under such a wide range of light conditions, is thought to be caused by a psychophysiological (or photo-neurologic) effect resulting from the reduction of high intensity stimulation in local areas of the visual field in conjunction with the removal of the blue light stimulation.

Another important and unexpected advantage of the inventive lens is the strong improvement in vision provided in bright light without discomfort to the eye. In other words, the user simultaneously sees very clearly with no discomfort from this intensely clear vision. It is hypothesized that this phenomenon is also a result of a photo-neurologic

or psychophysical response to the removal of blue light and high intensity glints reflected into localized areas in the visual field.

The removal of these glints and blue light appear to act synergistically to change the behavior of the retina resulting in the increased visual sensitivity and inducing a calming effect to the user. The inclusion of a polarizer substantially enhances the calming effect. It is again hypothesized that the removal of the high intensity areas of the visual field affects the neural response to the light and thus increases the calming effect of the blue blocking alone.

10 A general trait of sensory systems is that the sensitivity of the system to information input is affected by the intensity of the stimuli presented to it. In the case of the eye, damage is principally caused by intense exposure to short wavelength radiation. In the case of a visual field where there is a diffusely illuminated area and a specular reflection  
15 or the sun in that area, the retina is most sensitive to damage from the contribution of the specular portion.

The eye is able to see over a wide range of lighting conditions by changing the sensitivity of the retina as a function of the light input and by changing the diameter of the pupil. The settings for these factors are in  
20 part based on a tradeoff between a need for safety to the retina and the need to see well. Since the specular sources are disproportionately effective in causing damage to the retina, it is reasonable to hypothesize that specular sources would be disproportionately effective in supplying sensitivity settings to the retina. The cellular site for this effect could be  
25 Ricco's area in the ganglion cell receptive field center since it is known to be involved in setting the gain of receptor cells in the retina for simple brightness. Accordingly, the wavelength (or blueness) of a specular source, and the intensity of a specular source should enter into the control of the information handling of the retina and the apparent result is  
30 referred to as the "blue-glint retinal response." This effect was unknown before the reduction to practice of the instant invention.

Information processing in the eye enters into many neurological responses in the brain. In particular, the eye supplies information which sets neuroendocrine levels appropriate to sleep and alertness. It has also been suggested that light level and spectral composition enter into

seasonal behavior patterns involved in mood and sex hormone levels. Since the blue-glnt information processing response allows the blue, high intensity light to be disproportionately effective in stimulating sensitivity responses, it may also be involved in the calming effect which is far beyond that noted from blue blocking lenses alone. The effect of the blue glint removal may not be limited to the retina, but may also have a psycho-physical effect on the brain. The brain may be affected as a result of the blue-glnt retinal response, thereby affecting mood and instilling the observed calming effect.

10 This blue glint phenomenon may have evolved in response to the particular damaging effects of high intensity blue light on the retina. There is a theory of retinal radiation damage involving the concept of daily damage accumulation and of renewal mechanisms that repair the damage by removing and replacing the damaged molecules and  
15 structures or cells. In addition, byproducts of the renewal process (amino acid sequencing defects in proteins and the formation of other undegradable molecular debris such as lipofuscin) can also accumulate resulting in impaired cell function. Under this theory, the retinal cells progressively accumulate damage, and when damage rates are higher  
20 due to harmful chemical or radiation exposure, the accumulation of damage is also higher.

Superimposed upon this general increase in debris from the renewal process in the retina, there are shorter term accumulations of damage which occur during light exposure during the day which is then  
25 removed and replaced overnight. However, the renewal mechanisms have finite rates of repair, and if the light exposure is over a certain point, the renewal processes overnight are insufficient to bring the retina back to close to its previous state by morning. This damage is similar to the progressive accumulation of damage described above, and contributes  
30 to it, but it is in addition to this progressive accumulation of damage, and affects the function of the eye on a shorter time scale. An example of this is the repair activity noted in night vision degradation in experiments with lifeguards. For damage above the night vision degradation threshold, the experiment disclosed that the night vision would gradually improve overnight but that the gains would lag below the level of vision the night



before. If adequate protection was given during the day however, the eye's night vision would return to normal after a few weeks as the cell renewal processes caught up.

With longer exposure times, the time available for renewal mechanisms to act become more significant. For solar retinitis, the time scale is short. The rate of damage is sufficiently high to cause a lesion and the continuing exposure would result in blindness in a short time. Night vision degradation, in contrast, requires less irradiation and thus lower damage rates than solar retinitis and is more affected on a day to day basis by the efficacy of repair mechanisms of the eye.

When the rate of damage overall is equal to the rate of renewal overall, a threshold is reached above which damage gradually accumulates resulting in the progressive loss of vision. This damage threshold is used in setting the standards discussed in this disclosure and is the basis for the design of the inventive lens.

Functional impairment of the retina is associated with a threshold for damage for a particular time scale of exposure. The threshold for a retinal lesion is at a higher irradiance or for a longer time scale than for night vision impairment.

This lower irradiance, longer term damage which has been quantitatively demonstrated by researchers, has shown that for a given wavelength, smaller irradiances result in damage if the exposure time is longer and for a given irradiance, longer wavelengths can produce damage if the exposure time is longer. To extrapolate to longer time scales and lower irradiances, the efficiency of renewal mechanisms would become more significant in determining the threshold for functional impairment resulting from exposure to damaging influences such as radiation. It has not been proven that the damage mechanism is the same for short time scales as long ones, and the site of injury has been suggested to shift from the retinal pigment epithelium to the receptor layer for long term damage. However, the basic idea of radiation induced damage due to the formation of impaired renewal mechanisms still holds even in this case as well as an action spectrum similar if not identical to the blue light hazard spectrum. This suggests that for long time scales such as a lifetime, the renewal mechanisms are

important determinants of the long term prognosis of blindness or eye health.

Damage from high energy visible (blue and violet) and UV photons is due to the formation of reactive molecules which form when cellular materials are struck by the photons. The repair mechanisms involve transport and conversion of highly reactive molecules to less reactive forms without allowing these molecules to react with the cellular materials. The lysosomal enzyme systems that remove damaged molecules are capable of handling sub-threshold damage rates. However, over the threshold, damaged molecules accumulate resulting in impairment to the functions of the cell as the reactive molecules react with the cellular materials and enzymes. This "threshold dependent" damage would be above and beyond the "normal" accumulation of lipofuscin associated with renewal processes. Therefore it is advisable to stay below the threshold in the interest of limiting long term damage to the retina.

The irradiance relative to the threshold is then the single most important factor determining the safety and related comfort of a sunglass lens. The mathematical analysis below has shown that under some light conditions, a filter without a polarizer is insufficient to stay below the calculated threshold. Accordingly, in the area of a glint image on the retina, the tissues on a local scale are closest to threshold and likely to go over it. In order for a conventional sunglass to be able to reduce the glints to a level where they are below threshold, the lenses would have to be so dark as to be nearly useless for vision. The damage to the retina takes place on a small spatial scale, and thus the threshold crossing effect of the glints is under some conditions the only significant damage to the eye during irradiation with blue blocking lenses.

The intensity of photons in the glint can also contribute to the photochemical damage due to the heating of the retina in the vicinity of the glint. High intensity glints of light in the visual field cause a localized area of the retina to be exposed to far more photons per second than outside the focussed glint area. Even wavelengths which are relatively harmless (longer than 600 nanometers) can, under some circumstances cause damage due to thermal heating of the retina in those areas.

Thermal heating potentiates photochemical degradation of the receptor segments in the retinal cells, thus encouraging damage to the rods and cones of the eyes. By removing the heated areas, the blue light which impinges on the retina is thus rendered less harmful. The additional  
5 contributory effect of the glint may cause the damage threshold to be passed in a given retinal cell, and photochemical damage would then occur in that location of the glint image. Without the glint, the blue photons may be below threshold damage level and no irreversible damage would occur. Removal of the glints removes the heating and  
10 thus the passing of the threshold for damage by the blue light in those areas. This thermochemical potentiation of damage has not been taken into account quantitatively in this analysis.

Removing the glints substantially improves the safety of the sunglass without resorting to the more extreme blue blocking that would  
15 be necessary to achieve the same degree of retinal safety. It has been found by researchers and those companies which make blue blocking glasses, that many people are disoriented and even nauseated by blue blocking lenses. The effect was so strong that many companies sought the medical market only, ignoring the majority of sunglass wearers in the  
20 U.S.

Blue light exposure has also been shown to affect the levels of thyroxin differently from other wavelengths of light in an animal study and this effect might occur in humans. Furthermore, in other animal studies, the blue light has been shown to block the release of melatonin from the  
25 pineal gland better than other wavelengths of light. Thus, wearing blue blocking glasses may result in an increased release of melatonin from the pineal. The ramifications of this melatonin increase may be far reaching since melatonin has been shown to affect other hormonal systems which in turn affect metabolism and sex hormones. It is known  
30 that manic-depressives' melatonin levels are hyper-sensitive to light levels. Additionally, some people have "winter depression" during the dark short days of winter which was then relieved by exposure to high intensity blue-rich fluorescent lights. Melatonin is also known to increase retinal degeneration under high light illumination.

Researchers generally agree that humans are genetically

adapted to a forest cover environment and thus would normally get less blue light exposure and thus more melatonin. Hence wearing the inventive lenses may return melatonin levels to a higher and more historically normal and more healthful level. While blue blocking to some degree may modify the endocrine systems in animals, it appears likely that they modify them for the better, returning the system to a more healthful, natural and balanced state.

For these reasons, the blue blocking is desirable but should not necessarily be done to excess so long as the retina is well protected. Since the benefits to the retina of blocking blue light are very firmly established, some blue blocking is desirable. The ideal situation exists where the glints are removed, so that the illumination is relatively uniform. Under these conditions, a minimum of blue light can be blocked while still keeping all retinal cells below threshold.

Accordingly, a range of lenses which selectively block from 300 to 450 nanometers and which have a sharp cut-on filter from 450 to 550 nanometers with a polarizer have been selected so that the individual has an appropriate amount of short wavelength blocking for adequate protection under a wide range of light environment conditions.

20.

#### Analysis Demonstrating the Value of the Inventive Lens

An analysis was performed to calculate in absolute terms the intensity of hazardous light reaching the eye under various circumstances with optical filters interposed between the eye and the light source. This analysis considers the effect of polarizers on reducing the intensity of light under different hazardous outdoor light conditions. The hazards were compared with known exposure levels for solar retinitis and night blindness resulting in absolute standards for sunglass performance. Under some circumstances only the inventive lens were sufficient to meet the standard.

It has been shown that high levels of blue light (400-500 nanometers range) reaching the retina are harmful to visual performance and the health of the eye. In order to determine the hazard under real and pertinent conditions, models of actual light environment conditions were made. Within those environments, two broad categories of

hazardous blue light sources were considered: "glints" and "extended sources".

"Glints" consist of essentially specular reflections of the sun. These sources have some degree of polarization due to the nature of reflections. Glints also subtend a small angle of the eye's field of view. The "extended sources" included diffuse reflections of the sun from such high reflectivity surfaces as snow and clouds as well as the blue light of the sky. These sources subtend a large angle in the eye's field of view and expose large areas of the retina to an essentially uniform level of illumination.

#### Calculation of Hazard Values for Specular Reflection Sources.

A glint is a reflected image of the sun as viewed by the observer's eye. The plane of incidence ( defined by the incident and reflected ray ) is vertical for all reflections studied in this analysis. This is because most commonly encountered reflections of the sun are reflected from horizontal or nearly horizontal surfaces. The size of this image is given by :

$$[1] \quad y_i = (y_{sol}/s_{sol}) * (r/2)$$

20

Where:

$y_i$  = diameter of the image of the sun.

$y_{sol}$  = diameter of the sun.

$s_{sol}$  = distance to the sun.

$r$  = radius of curvature of the reflective surface ( $r > 0 \implies$

25 convex reflector)

The distance the image of the sun lies behind the convex reflector is given by:

$$[2] \quad s_i = -1/(2/r + 1/s_{sol})$$

Where:

30  $s_i$  = The distance the image of the sun lies behind the convex reflector.

$s_{sol}$  = distance to the sun.

$r$  = radius of curvature of the reflective surface ( $r > 0 \implies$

convex reflector)

The total radiance of the image of the sun is given by:

$$[3] \quad L_i = R * L_{sol} * T_{atmosphere}.$$

Where:

$L_i$  = The radiance of the image of the sun.

$R$  = the combined reflectance of the reflecting surface.

5  $T_{atmosphere}$  = the transmission of the Earth's atmosphere.

$L_{sol}$  = radiance of the sun as viewed from above the Earth's atmosphere.

The preceding analysis does not consider polarization effects. To consider polarization effects, different reflectance coefficients must be used for the two axes of polarization defined by the plane of incidence. The light emanating from the image of the sun is composed of both horizontally polarized light and vertically polarized light. Since we are assuming a vertical plane of incidence, and since sunlight is randomly polarized, the radiance of vertically polarized light and horizontally polarized light are given by:

$$[4a] \quad L_{ihorizontal} = L_{iperp} = (L_{sol}/2) * T_{atmosphere} * R_{perp}$$

$$[4b] \quad L_{ivertical} = L_{ipara} = (L_{sol}/2) * T_{atmosphere} * R_{para} \quad \text{and,}$$

$$[4c] \quad L_{ihorizontal} + L_{ivertical} = L_i$$

$$[4d] \quad (R_{perp} + R_{para})/2 = R$$

20 Where:

$L_{ivertical}$  = the radiance of vertically polarized light radiating from the image of the sun in Watts/(cm<sup>2</sup>\*steradian)

$L_{ihorizontal}$  = the radiance of horizontally polarized light radiating from the image of the sun in Watts/(cm<sup>2</sup>\*steradian)

25  $R_{perp}$  = the reflectance coefficient for light which is polarized perpendicular to the plane of incidence (horizontally polarized light)

$R_{para}$  = the reflectance coefficient for light which is polarized parallel to the plane of incidence (vertically polarized light)

The factor of 2 enters in because half of the incident sunlight is horizontally polarized and half is vertically polarized.

The reflectance coefficients for reflection of light off of a dielectric material (such as glass or water) are given by:

$$[5a] \quad R_{perp} = [\sin(q_i - q_t)/\sin(q_i + q_t)]^2$$

$$[5b] \quad R_{para} = [\tan(q_i - q_t)/\tan(q_i + q_t)]^2$$

$$[5c] \quad q_t = (n_i/n_t) * q_i$$

Where:

$q_i$  = the angle of incidence measured relative to the normal of the plane.

$q_t$  = the angle of transmittance of the light into the dielectric  
5 medium.

$n_i$  = index of refraction of incident medium (air)

$n_t$  = index of refraction of transmitted medium (glass, water, etc)

$R_{para}$  = Reflectance coefficient for light polarized parallel to the plane of incidence (vertically polarized light).  $R_{para}$  = (Intensity of  
10 reflected light which is polarized parallel to plane of incidence)/(Intensity of incident light which is polarized parallel to plane of incidence)

$R_{perp}$  = Reflectance coefficient for light polarized perpendicular to the plane of incidence (horizontally polarized light).  $R_{perp}$  = (Intensity of reflected light which is polarized perpendicular to plane of  
15 incidence)/(Intensity of incident light which is polarized perpendicular to plane of incidence)

The angle subtended by the image of the sun as viewed by the observer's eye is given by:

$$[6] \quad a_e = \text{Atan}(y_i/(s_e+s_i))$$

20 Where:

$a_e$  = The angle subtended by the image of the sun as viewed by the observer's eye.

$y_i$  = diameter of the image of the sun.

$s_e$  = distance between observer's eye and reflecting surface.

25  $s_i$  = distance image is behind reflecting surface.

The corneal irradiance caused by the image of the sun is given by:

$$[7] \quad E = \pi \cdot L_i \cdot (\sin(q_e))^2$$

Where:

30  $E$  = corneal irradiance caused by image of the sun

$L_i$  = radiance of the image of the sun

$q_e = a_e/2$  = half angle subtended by the image of the sun as viewed by the observer's eye.

The different reflection coefficients for the two axes of polarized light lead to separate radiances and irradiances for each axes of

polarization. The irradiances for the horizontal and vertically polarized light are given by :

$$[8a] E_{\text{horizontal}} = \pi \cdot L_{\text{horizontal}} \cdot (\sin(q_e))^2$$

$$[8b] E_{\text{vertical}} = \pi \cdot L_{\text{vertical}} \cdot (\sin(q_e))^2$$

5 Where:

$E_{\text{horizontal}}$  = the corneal irradiance of horizontally polarized light caused by the image of the sun.

$E_{\text{vertical}}$  = the corneal irradiance of vertically polarized light caused by the image of the sun.

10 The different reflection coefficients for the two axes of polarized light lead to separate radiances and irradiances for each axis of polarization. The reflectance coefficients shown above indicate that the light which is polarized perpendicular to the plane of incidence is reflected more strongly. Consequently, polarized sunglass lenses are  
15 oriented so that they block the light which is polarized perpendicular to the plane of incidence. Since the polarizers used are aligned so that they block virtually all of the light which is polarized perpendicular to the plane of incidence, the total corneal irradiance after the light from the image of the glint has passed through the polarizer is given by:

$$20 \quad [9] \quad E_p = E_{\text{vertical}} = \pi \cdot L_{\text{vertical}} \cdot (\sin(q_e))^2 \\ = \pi \cdot (L_{\text{sol}}/2) \cdot T_{\text{atmosphere}} \cdot R_{\text{para}} \cdot (\sin(q_e))^2$$

The standards concerning exposure to hazardous levels of blue light are expressed in terms of hazard-weighted irradiance or  
25 hazard-weighted radiance. This hazard function incorporates the fact that certain wavelengths of light are more damaging to the retina than others. In general, the shorter the wavelength of light the more damaging it is. This is due to the photochemical nature of the actinic damage mechanism. However, the ultraviolet (UV) wavelengths of light  
30 are largely absorbed by the cornea, lens, and aqueous and vitreous humors of the eye and therefore very little of the short wavelength UV light reaches the retina. These two effects combine to produce a retina hazard function which peaks in the blue region of the spectrum at about 450 nm. The equations for calculating the hazard weighted radiances and irradiances are given by:



For extended sources:

1400nm

$$[10] L_b = \sum L_{\text{source}}(\lambda) \cdot BLH(\lambda) \cdot \Delta\lambda$$

5                    400nm      for  $t > 10000$  seconds

Where:

$L_b$  = the hazard weighted radiance in  $W/(cm^2 \cdot sr)$

$L_{\text{source}}(\lambda)$  = the spectral radiance of the source as a function of wavelength in  $W/(cm^2 \cdot sr \cdot nm)$

10                     $BLH(\lambda)$  = the blue light hazard function as a function of wavelength

$\Delta\lambda$  = the interval of wavelength at which measurements are taken and the calculation is made. In this study spectral data was taken at intervals of 5nm.

15                    And for point sources subtending less than 11 millirad (approximately 0.62 deg.)

1400nm

$$[11] E_b = \sum E_{\text{source}}(\lambda) \cdot BLH(\lambda) \cdot \Delta\lambda$$

400nm      for  $t > 10000$  seconds

20                    Where:

$E_b$  = the hazard weighted irradiance in  $W/cm^2$

$E_{\text{source}}(\lambda)$  = the spectral irradiance of the source as a function of wavelength in  $W/(cm^2 \cdot nm)$

$BLH_\lambda$  = the blue light hazard function as a function of wavelength

25                     $\Delta\lambda$  = the interval of wavelength at which measurements are taken and the calculation is made. In this study spectral data was taken at intervals of 5nm.

The standards given for the two types of hazardous sources are given by researchers in the field as follows:

30                    [12]  $L_b \leq 0.01 W/(cm^2 \cdot sr)$  for  $t \geq 10^4$  seconds

[13]  $E_b \leq 1 \text{ microwatt}/cm^2$  for  $t \geq 10^4$  seconds

To calculate the effect of a spectrally selective filter on the hazard weighted irradiance and radiance of a hazardous source, the spectrum of the source as viewed through the selective filter must be calculated as follows:

$$[14] L_{\text{filteredsource}}(\lambda) = T_{\text{filter}} * L_{\text{source}}(\lambda) \quad \text{and,}$$

$$[15] E_{\text{filteredsource}}(\lambda) = T_{\text{filter}} * E_{\text{source}}(\lambda)$$

The blue light hazard of the source when viewed through the filter can now be calculated by inserting  $L_{\text{filteredsource}}(\lambda)$  in place of  $L_{\text{source}}(\lambda)$  in eqn [10] and inserting  $E_{\text{filteredsource}}(\lambda)$  in place of  $E_{\text{source}}(\lambda)$  in eqn [11].

Finally the blue light hazard of a glint as viewed through the combination of a spectrally selective filter and a properly oriented polarizer is calculated by substituting  $L_{\text{vertical}}$  in place of  $L_{\text{source}}$  in eqn [14] and substituting  $E_{\text{vertical}}$  in place of  $E_{\text{source}}$  in eqn [15] and proceeding with the calculation by inserting the resulting source radiance and irradiance in eqns [10] and [11] respectively.

In this analysis these extended sources are assumed to have a negligible degree of polarization. Blue skylight is horizontally polarized to some degree in the direction opposite the position of the sun but most extended sources do not polarize light appreciably.

The quantity of importance for extended source optical hazards is the radiance,  $L_d$ . For extended sources such as the blue sky, the radiance is measured directly and weighted by the procedure described by eqn [11] to produce the blue light hazard weighted radiance. For extended sources illuminated by the sun which are essentially white lambertian scatterers such as fresh snow, dry white sand, or the top of a cloud deck the radiance is given by:

$$[16] L_d = R_d * L_{\text{sol}} * (\sin(q_{\text{sol}}))^2$$

The blue light hazard weighted radiance of solar illuminated extended sources is given by:

$$[17] L_{\text{db}} = R_d * L_{\text{solb}} * (\sin(q_{\text{sol}}))^2$$

Where:

$L_{\text{db}}$  = the blue light hazard weighted radiance of the extended scattering source which is illuminated by the sun.

$R_d$  = the diffuse reflectance coefficient of the scattering surface.

$q_{\text{sol}}$  = the half angle subtended by the sun.

$L_{\text{solb}}$  = the blue light hazard weighted radiance of the sun as calculated below:

1400nm

$$[10] L_{\text{solb}} = \sum L_{\text{sol}}(\lambda) * BLH(\lambda) * \Delta\lambda$$

400nm for  $t > 10000$  seconds

Where:

$L_{solb}$  = the hazard weighted radiance of the sun in  $W/(cm^2 \cdot sr)$

$L_{sol}(\lambda)$  = the spectral radiance of the sun as a function of  
 5 wavelength in  $W/(cm^2 \cdot sr \cdot nm)$

$BLH(\lambda)$  = the blue light hazard function as a function of  
 wavelength

$\Delta\lambda$  = the interval of wavelength at which measurements are taken  
 and the calculation is made. In this study spectral data was taken at  
 10 intervals of 5nm.

#### Standards Based On Effects

There have been several research reports presented which describe the microanatomical and functional effects of exposure to  
 15 certain wavelengths of light. One of these reports found that the 35 to 50 percent transmission of conventional sunglasses was unable to provide protection lasting longer than a day or so while 10 to 12 percent transmission sunglasses are adequate to protect night vision for longer periods. It has also been argued that short wavelength visible light is the  
 20 effective part of the spectrum in their observed degradation of night vision. From this premise, and by using the original calculations shown above, we are able to calculate that the hazard weighted radiance the subjects were exposed to and thus determine the threshold for night vision protection. It appears that the threshold for night vision  
 25 degradation is at approximately  $0.2 \text{ mWatt}/(cm^2 \cdot sr)$ . The threshold for solar retinitis is  $10 \text{ mWatt}/(cm^2 \cdot sr)$ .

Some retinal irradiance studies have been in terms of exposure to extended sources while others are in terms of specular sources. The image of a specular source is not perfectly focussed and is moved across  
 30 the retina by the motion of the eye resulting in a larger effective area and lower effective irradiance than would be expected if the irradiance were perfectly focussed in one place. A  $1 \text{ microWatt}/cm^2$  point source produces the same retinal irradiance as a  $10 \text{ milliwatt}/cm^2 \cdot sr$  extended source over the area it affects. The resulting damage thresholds are shown in the Table below:

## Thresholds for Damage

<u>Damage</u>	<u>Specular</u>	<u>Extended</u>
Solar Retinitis	1.0 microW/cm <sup>2</sup>	10.0 mW/(cm <sup>2</sup> *sr)
Night Vision Loss	0.02 microW/cm <sup>2</sup>	0.2mW/(cm <sup>2</sup> *sr)

5

Standards based on the above Table are presently not used in the sunglass industry and are an innovation of the inventors. The standard is referred to as the Eye Protection Factor (EPF). The EPF standard is based on how well the sunglass blocks harmful radiation relative to the thresholds described above for a standard condition and results in a rating number which a consumer can use in a manner similar to the Sun Protection Factor (SPF) numbers shown on suntan lotions.

In view of the above disclosure it is the primary object of the invention to disclose a sunglass lens design and process for making the lens that uses a combination dye and a polarizer to produce a lens that substantially blocks ultraviolet radiation, blue light, and horizontally polarized light. The result of this is a lens that:

- \* can be used for an extended period of time without damage or discomfort,
- \* improves visual acuity,
- \* protects against long term eye damage,
- \* preserves night vision,
- \* reduces risk of eye disease,
- \* reduces the onslaught of radiation which results in aging of the eye tissues and taxes regenerative processes in the eye.

In addition to the primary objects it is also an object of the invention to have a lens that is:

- \* cost effective and safe to own,
- \* cost effective and safe to manufacture,
- \* mechanically easy to handle and use,
- \* adaptable to a variety of sunglass frames,
- \* adaptable to a variety of visual environments.
- \* can be used in applications other than for sunglasses

These and other objects and advantages of the invention will

become apparent from the subsequent detailed description of the invention and the claims taken in conjunction with the accompanying drawings.

5

### BEST MODE FOR CARRYING OUT THE INVENTION

The best mode for carrying out the inventive Ultraviolet radiation and blue light blocking polarized lens 12 is presented in terms of a preferred embodiment that is primarily designed for mounting on a pair of  
10 sunglasses. The lens 12 substantially blocks horizontally polarized light and selectively blocks wavelengths in the electromagnetic spectrum that lie between 300 and 549 nanometers and allows 30 to 40 percent of wavelengths in the visible portion of the spectrum, that are longer than 625 nanometers, to be transmitted. The selective blocking is controlled  
15 by a sharp cut-on filter selected to cut-on at either 450, 500, 515, 530, or 550 nanometers. Only wavelengths longer than 300 nanometers need be blocked due to atmospheric absorption of shorter wavelengths.

The lens 12 in the disclosure that follows refers to various terms. To facilitate the understanding of the invention, these terms are initially  
20 defined.

\* Electromagnetic spectrum. For the purpose of this invention, the spectrum has a lower limit of 300 nanometers and an upper limit of 780 nanometers. The visible portion of the spectrum is further defined as falling between 400 and 780 nanometers.

25 \* Transmission. The percentage of light that is passed through a lens.

\* Blocking. The opposite of transmission and is a measure of the percentage of light that is either reflected by the surface or surface coatings or absorbed by the dye or plastic of the lens.

30 \* Substantially blocking. When used with reference to wavelengths, it is defined as blocking over 99 percent of the incident radiation or transmitting less than one percent of the incident radiation at each and every wavelength. When used with reference to polarization, it is defined as blocking 80 percent or more of the horizontally polarized incident radiation at each and every wavelength.

\* Sharp cut-on. For the purpose of this invention, sharp cut-on is defined in the context of a dye or filter, having a cut-on slope that rises more than one half percent (0.5 %) change in transmission for every one nanometer of increasing wavelength change. The cut-on slope is that  
5 portion of the transmission spectra of a cut-on dye that represents the transition between substantially blocking region and the substantially transmissive region.

\* Combination dye. For the purpose of this invention, a combination dye is defined as being made from a mixture of two dyes  
10 whose ultraviolet transmission holes do not substantially overlap.

The preferred embodiment of the invention, as shown in FIGURES 1 through 8, is comprised of the following six major elements: a (polarizer) plastic lens 12, a sharp cut-on filter 14, a horizontally polarizing film 16, a combination dye 18, a dispersed orange three  
15 sharp-cut-on dye 20, a dispersed red two sharp-cut-on dye 22, and a dispersed yellow twenty-three sharp-cut-on dye 24.

The lens 12 as used in this invention is primarily a blocking lens rather than a transmissive lens and is cast from an optical plastic or optical glass. In the preferred embodiment, the lens is cast from an  
20 optical hard-resin plastic made from a diallyl glycol carbonate monomer such as a CR-39 polymer. CR-39 is a registered trademark of the Pittsburgh Plate Glass Company having its principal offices in the United States of America. The CR-39 polymer possesses properties that under controlled conditions allows the lens to be easily dyed with the selected  
25 dispersed dyes, described infra, that provide the required wavelength blocking.

Sunlight is composed primarily of visible light and invisible radiations known as Ultraviolet and Infrared. Most persons exposed to bright light, especially sunlight, for any period of time are more  
30 comfortable when wearing sunglasses that block wavelengths in the 400 to 780 nanometer range. Conventional sunglass lenses that block in this range reduce excessive glare, which can cause eye discomfort but they hamper visual acuity because of their necessarily low transmission.

The blocking feature of the inventive lens 12 is achieved by the sharp cut-on filter 14 which is used in combination with the horizontally

polarizing film 16. The function of the filter 14 is best understood by referring to FIGURE 1 which discloses the spectral curves of the invention.

5 The spectral curves are divided into a blocking zone, a transition zone and a transmissive zone. The curves define the transmission spectra of a family of sunglass lenses having sharp cut-on filters at wavelengths of 450, 500, 515, 530, and 550 nanometers.

10 If a filter 14 having a cut-on at 450 nanometers is selected, the blocking zone and the transmissive zone are common to other members of the family. In this case, wavelengths between 300 and 449 nanometers are substantially blocked up to the transition zone where the sharp cut-on filter 16 cuts-on at 450 nanometers and steeply rises up to the transmissive zone where 30 to 40 percent of the wavelengths that are longer than 625 nanometers are transmitted.

15 If a cut-on filter 14 other than at 450 nanometers is selected, the range of the blocking zone increases (displaced horizontally). For example, if a 500 nanometers cut-on filter is selected, wavelengths between 300 and 499 nanometers would be blocked up to and into the transition zone where the sharp cut-on filter 14 would cut-on at 500  
20 nanometers; likewise, a cut-on at the maximum 550 nanometer would allow wavelengths between 300 and 549 nanometers to be blocked before the cut-on filter cuts-on at 550 nanometers. In all cases of the preferred embodiment, the transmissive zone, beyond 625 nanometers, remains fully open transmitting between 30 to 40 percent at each and  
25 every wavelength out into the infrared region. In the preferred embodiment, 30 to 40 percent of wavelengths longer than 625 nanometers, are transmitted. However, the transmittance of the transmissive zone beyond the 625 nanometer point can be increased to any range between 10 and 90 percent by the proper selection of the  
30 combination dye 18 and the polarizing film 16.

The principal novelty of the invention is in the ability of the lens 12 by means of the sharp cut-on filter 14 in combination with the polarizer 16 to block ultraviolet radiation, blue light and horizontally polarized light. While a calming effect is achieved by wearing only blue blocking lenses, the inclusion of the polarizer 16 substantially increases the calming effect

and substantially improves vision without visual discomfort. Additionally, the inventive lens allows a specific degree of safety without affecting the hormonal balance of the body any more than necessary. These surprising and unexpected results have been explained by way of a hypothesis after the combination was reduced to practice and the effects were experienced first hand. The complete explanation of some effects must await further understanding of the human brain and the interaction of the human eye with light. In contrast, the limited improvement in visual acuity and eye protection afforded by the elimination of the Ultraviolet radiation and the reduction of blue light content is well recognized by researchers in the field.

The process that resulted in a successful reduction to practice of the innovative lens 12 was not obvious at the outset. The economic production of UV and blue blocking polarizing sunglasses is hampered by the fact that the currently manufactured plastic lens polarizers generally consist of a sheet of heat sensitive polarizing film laminated between two layers of the CR-39 polymer lens. The polarizer is formed by stretching the thin film so that the film molecules are aligned in a way that light passing through the lens is polarized. When this film is laminated in the cast CR-39 polymer it can withstand the heating that is normally used to hot-dip dye lenses with cosmetic tints. These tints are usually very light shades of pastel colors that add a decorative and individualizing feature to the lens. The requirement for dyeing the lens to the level that is required by the instant invention for full eye protection and maximum visual acuity required a time and temperature in the hot-dip dye vessels that destroyed the polarizing effect of the lens 12.

It is also known in the art that commercially available dispersed sharp cut-on dyes suitable for the hot-dip dyeing of CR-39 plastic lenses have a significant UV radiation transmission. This UV transmission is sometimes referred to as a "UV hole". The cut-on dyes, as shown in FIGURE 2, Curves A and B, used in this invention each have a "UV hole". If the lens 12 is allowed to become sufficiently dark by extending the dye time, the UV hole will be absorbed to less than one percent. Unfortunately, the time required for this UV reduction will cause the polarizer to fail due to the time the polarizing film 16 is heated in the dye



and exposed to the dye chemicals.

The minimum time the lens 12 must be in the dye is determined by how long it takes to fill the UV hole. By using the combination dye 18, as shown in FIGURE 3 Curve C, the time and temperature required to  
5 remove the UV holes can be reduced as shown in FIGURE 2 curve A to allow the polarizer film 16 to survive the manufacturing process.

The hot-dip dyeing process is the most commonly used process for dying ophthalmic lenses and is the basis for the best mode process. The dyes that are used are dispersed dyes, that is, they are molecules of  
10 oil soluble dye encased in a surfactant skin. The dyes are dispersed in water at a temperature of  $98 \pm 1$  degree centigrade. When an encased molecule of dye contacts the plastic surface the surfactant skin breaks and the oil soluble dye molecule diffuses into the surface of the plastic lens. Increasing the dye concentration in the boiling water dispersion  
15 does not increase the dyeing rate significantly but the danger that the dispersion will break down increases dramatically. When many dye molecules collide with one another their surfactant skin can break down and they can aggregate into a greasy lump of dye molecules that have lost their surfactant skins. This lump sticks to the lens surface where it will  
20 form a visible spot on the lens. If the particular sharp cut-on dispersed dye is allowed to diffuse into the plastic for a long enough time and at a high enough temperature the UV hole will be reduced to acceptable levels to provide adequate eye protection and the required cut-on wavelength.

25 What was not known to the ophthalmic lens dying industry was the fact that some dyes have their UV holes at slightly different wavelengths from one another. This off-set of the UV holes in different dyes is the discovery that induced the process part of the instant invention.

The instant invention makes the sharp cut-on dyeing of heat  
30 sensitive polarizers technically and economically feasible. In the Best Mode Table, as shown in FIGURE 3, it can be observed that a combination of a dispersed yellow twenty-three dye 24 and a dispersed orange three dye 20 will produce the desired results of a sharp cut-on filter in the shorter (light orange) wavelengths; and a combination of a dispersed orange three dye 20 with a dispersed red two dye 22 will

produce a sharp cut-on filter with longer (dark orange) wavelengths. The dye concentrations were empirically determined to produce a combination of dyes that would not produce the greasy lumps and would dye the heat sensitive polarizer lens fast enough that they would not be destroyed. The best mode table of FIGURE 3 provides the dye combination 18, the required time and temperature to provide the specific cut-on wavelength desired. The table also includes the recommended uses for the UV and blue blocking polarizing lens 12. Although not considered a preferred method, the lens may be applied by the combination dye at a temperature of  $37 \pm 1$  degree centigrade where the time is between 7 and 10 days.

The polarizer 16 combined with the lens 12 adds a polarizing screen that blocks horizontally polarized light. The film used, as previously mentioned, is sensitive to chemical and temperature damage. Thus a polarized film that is exposed to heat and chemicals (such as a dye) after a period of time will fail and cease to block the polarized light. A typical polarizing film 16 failure curve is shown in FIGURE 4 Curve A. The area above Curve A constitutes the polarizer failure region while below Curve A is the safe region. Therefore, to safely dye polarizing lenses, the dyes must be selected so that the required optical density can be achieved within the enclosed area shown in FIGURE 4 area B which is below the polarizer failure Curve A. In other words, the dye time and temperatures shown in FIGURE 3 must be selected to fall within the safe region shown in area B. The downward inflection of Curve A is due to the chemical degradation of the polarizing lens that occurs after extended periods of time in the dye at low temperature.

A search was made for sources of polarizers which had as high a Curve A as possible. One such lens, a heat resistant polarizer which did not delaminate or fail at required time and temperature, is known as "R-plano smoke color as in invoice 10-324" and is procured from the Alpha Company Ltd. in Japan. Of the numerous sources examined, an exceptionally heat resistant lens manufactured by the Polarlite Co. in Seattle, Wa., was also found that could sometimes be dyed with a single dye (orange or yellow) for longer times and higher temperatures. However, because of the expensive heat resistant lens, the use of one

dye is not considered the best mode, but it is another possible way to make the lens 12.

Other ways to make the polarized lens include:

- \* laminating a film onto or between a pre-dyed UV and blue blocking lens blank,
- \* dying the lens with an embedded polarizer in a solvent dye, and/or mixing the dye into the monomer before molding around a polarizing film.

While under some circumstances these techniques could be desirable, their complexity, tooling costs and minimum manufacturing quantities make them economically unfeasible for smaller scale operations.

For intermediate scale production, lenses can be dyed using the best mode time, temperatures and dye concentrations shown in FIGURE 3 and as structurally shown in FIGURE 5 section A. In this small scale process a lens 12 is captured in a wire holder 52 and placed in a small vessel 50 of the aqueous dispersed dye combination 18 operating at  $98 \pm 1$  degree Centigrade. The vapor bubbles 54 rise from the bottom of the pot and stir the dye in contact with the lens 12. A thermometer 56 is sometimes used to measure the dye temperature to predict the time required to obtain the required spectral characteristics. The pot is heated electrically.

For large scale production, lenses can be dyed using the best mode time, temperatures and dye concentrations in FIGURE 3 and as structurally shown in FIGURE 5 section B. In this large scale process the lenses 12 are captured in a plastic rack type holder 58 and placed in a large vessel 50 of the aqueous dispersed dye combination 18 operating at  $98 \pm 1$  degree Centigrade. The vapor bubbles 54 rise from the bottom of the vessel and stir the dye in contact with the lenses 12. The large vessel is normally heated by a natural gas flame.

After the lenses are dyed they are edged by standard industrial edging machines well known in the ophthalmic industry. The lenses are then mounted in metal or plastic frames suitable for the various occupations and recreations mentioned in the Best Mode Table of FIGURE 3. Before the completed sunglasses are shipped they are

compared to spectral standards to insure they meet the required cut-on filter requirements and the required polarization performance. The sunglasses are inspected for imperfections and proper assembly in the frames.

- 5       The polarizing film 16 as used with various combinations of dye locations is shown in crosssection in FIGURES 6, 7, and 8.

      In FIGURE 6, the dye is absorbed into the surface of the plastic lens 12 and the polarizing film 16 is laminated between two lens halves of cast or preformed plastic. The dye in this case is absorbed into the  
10   lens surface by a hot-dip dispersed dye process or a cold-dip solvent dye process.

      In FIGURE 7, the dye is mixed into the cast or preformed plastic lens 12 before the plastic is cast. Two halves are then laminated on either side of the polarizing film.

- 15       In FIGURE 8, the polarizing film 16 is laminated and the dye is in a coating or a laminated dyeable film that is bonded to the inside or outside of a plastic or glass lens 12. If the plastic or glass lens is photochromic and the dyeable film is on the inside (concave) of the lens the dyes will block the UV necessary to activate the photochromic  
20   material before the UV enters the eye.

      The synergistic effect of having a lens 12 with a polarizer 16 and a combination dye 18 that substantially absorbs blue light results in a lens that provides effective protection to the retina. The ideal situation is to minimize the need for blue blocking, by staying below the  
25   damage-repair threshold, and eliminating the thermal heating of the retina by the glints of light that pass across the retina as discussed in the Disclosure of the Invention section. The inventive lens 12 accomplishes this protection by blocking the horizontally polarized glints of light in the blue and UV wavelengths.

- 30       The combination dye 18 available for use with the lens 12 can be selected to substantially block all wavelengths in the electromagnetic spectrum between 300 and 549 nanometers. The specific cut-on wavelength selected within this spectral range is dependent upon the ultimate use of the lens and upon the time, temperature, and component dyes used to make the combination dye.

To process a lens 12, an optical plastic lens having a polarizing film 16 embedded therein is procured. If a cut-on wavelength at 450 nanometers is desired, a combination dye 18 is applied to lens 12 by a hot-dip combination dispersed dye process. The process essentially  
5 consists of immersing the lens into a vessel 50 containing a mixture of dispersed yellow twenty-three dye 24 and a dispersed orange three dye 20 in a concentration ratio of approximately 1 to 1. The lens 12 remains in the vessel for a period of 2.5 minutes at a temperature of  $98 \pm 1$  degree centigrade.

10 If a cut-on wavelength at 500 nanometers is desired the lens 12 is immersed into a vessel 50 containing a mixture of dispersed yellow twenty-three dye 24 and a dispersed orange three dye 20 in a concentration ratio of approximately 1 to 1 for a period of 5.0 minutes at a temperature of  $98 \pm 1$  degrees centigrade.

15 For a cut-on wavelength at 515 nanometers, the lens 12 is immersed into a vessel 50 containing a mixture of dispersed yellow twenty-three dye 24 and a dispersed orange three dye 20 in a concentration ratio of approximately 1 to 1 for a period of 12.0 minutes at a temperature of  $98 \pm 1$  degrees centigrade.

20 For a cut-on wavelength at 530 nanometers, the lens 12 is immersed into a vessel 50 containing a mixture of dispersed red two dye 22 and a dispersed orange three dye 20 in a concentration ratio of approximately 1 to 1 for a period of 4.5 minutes at a temperature of  $98 \pm 1$  degrees centigrade.

25 For a cut-on wavelength at 550 nanometers, the lens 12 is immersed into a vessel 50 containing a mixture of dispersed red two dye 22 and a dispersed orange three dye 20 in a concentration ratio of approximately 1 to 1 for a period of 12.0 minutes at a temperature of  $98 \pm 1$  degrees centigrade.

30 The best mode process for preparing the lens 12 is the hot-dip combination dispersed dye process described supra. Other processes that may also be used to apply the combination dye 18 or individual dyes include a laminate film process, a solvent dyed coating process, a cold-dip solvent-dye process and a pre-solvent-dyed molded-plastic process. The additional processes are well known in the art and are

therefore not described.

The processes that use the combination dye 18 may be used for all the sharp cut-on filters 14 described earlier. For filters that cut-on between 450 and 530 a single orange or red hot-dip dye may be used with special heat resistant polarizing lenses.

In this alternative process, if a cut-on at 450 nanometers is desired, the lens 12 is emersed into a vessel 50 containing the yellow twenty-three dye 24 for a period of 16 minutes at a temperature of  $98 \pm 1$  degrees Centigrade.

For a cut-on at 500 nanometers, the lens 12 is emersed into a vessel 50 containing the orange three dye 20 for a period of 5 minutes at a temperature of  $98 \pm 1$  degrees Centigrade.

For a cut-on at 515 nanometers, the lens 12 is emersed into a vessel 50 containing the orange three dye 20 for a period of 12 minutes at a temperature of  $98 \pm 1$  degrees Centigrade.

For a cut-on at 530 nanometers, the lens 12 is emersed into a vessel 50 containing the orange three dye 20 for a period of 18 minutes at a temperature of  $98 \pm 1$  degrees Centigrade.

For a cut-on at 550 nanometers, the lens 12 is emersed into a vessel 50 containing the red two dye 22 for a period of 18 minutes at a temperature of  $98 \pm 1$  degrees Centigrade.

The standard temperature of  $98 \pm 1$  degree as used in the preferred process may be changed to  $37 \pm 1$  degrees Centigrade. When the lens 12 is emersed at this lower temperature, the time required is about 7 to 10 days.

The combination dye 18 selected for use with the lens 12 is dependent upon its ultimate use. All reasonable viewing problems can be solved by using a polarized lens incorporating sharp cut-on filter 14. Five typical problem situations are considered: a lifeguard, a boater, a fisherman, a driver, and a pilot - the hazard weighted irradiance referred to in the discussion as well as other numerical and technical notations are derived and described in the Disclosure of the Invention section. The spectra of these lenses are shown in FIGURE 1.

The typical situation for the lifeguard is as follows: The time is noon, with the sun at zenith. The lifeguard is 8 meters away from the

water which has waves on it with a radius of curvature of 3 meters. The hazard weighted irradiance is  $3.27 \text{ microW/cm}^2$  which is far above the threshold for both solar retinitis and night vision loss. With a 500 cut-on filter, the irradiance drops to  $0.036 \text{ microW/cm}^2$  which is below the threshold for solar retinitis but above the threshold for night vision loss. With the addition of the polarizer, the hazard weighted irradiance is reduced to  $0.004 \text{ microW/cm}^2$  which is below the night vision loss threshold.

The typical situation for the boater is as follows: The time is noon, with the sun at zenith. The boater is 4.5 meters away from the water which has waves on it with a radius of curvature of 3 meters. The hazard weighted irradiance is  $8.20 \text{ microW/cm}^2$  which is far above the threshold for both solar retinitis and night vision loss. With a 515 cut-on filter, the irradiance drops to  $0.063 \text{ microW/cm}^2$  which is below the threshold for solar retinitis but above the threshold for night vision loss. With the addition of the polarizer, the hazard weighted irradiance is reduced to  $0.007 \text{ microW/cm}^2$  which is below the night vision loss threshold.

The typical situation for the driver is as follows: The time is noon, with the sun at zenith. The driver is 5 meters away from the glass window of the car in front of it. The glass window has a radius of curvature of 4 meters. The hazard weighted irradiance is  $39.60 \text{ microW/cm}^2$  which is far above the threshold for both solar retinitis and night vision loss. With a 530 cut-on filter, the irradiance drops to  $0.24 \text{ microW/cm}^2$  which is slightly above the threshold for solar retinitis and far above the threshold for night vision loss. With the addition of the polarizer, the hazard weighted irradiance is reduced to  $0.002 \text{ microW/cm}^2$  which is below the night vision loss threshold.

The typical situation for the fisherman is as follows: The time is noon, with the sun at zenith. The fisherman is 6 meters away from the water which has low waves on it with a radius of curvature of 6 meters. The hazard weighted irradiance is  $8.20 \text{ microW/cm}^2$  which is far above the threshold for both solar retinitis and night vision loss. With a 550 cut-on filter, the irradiance drops to  $0.045 \text{ microW/cm}^2$  which is below the threshold for solar retinitis but above the threshold for night vision loss. With the addition of the polarizer, the hazard weighted irradiance is

reduced to  $0.005 \text{ microW/cm}^2$  which is below the night vision loss threshold.

The most protective filter is the 550 cut-on. The 550 cut-on was selected as a limit because it is the greatest cut-on which does not  
5 interfere with red-green-yellow color discrimination which is needed for safety with traffic signals. This traffic signal recognition was determined experimentally. This lens is the one of choice for persons requiring the maximum protection such as those with diseased retinas i.e. Retinitis Pigmentosa, age-related macular degeneration etc. However, the lens  
10 may also be worn by others seeking maximum protection.

The typical situation for the police officer is as follows: The time is noon, with the sun at zenith. The driver is 5 meters away from the glass window of the car in front of it. The glass window has a radius of curvature of 4 meters. The hazard weighted irradiance is  $39.60$   
15  $\text{microW/cm}^2$  which is far above the threshold for both solar retinitis and night vision loss. With a 450 cut-on filter, the irradiance drops somewhat, but because of the need for color verity by the officer to correctly identify the color of vehicles, the officer is above threshold for both the night vision loss threshold and the solar retinitis threshold. However, he is still  
20 better off than if he did not utilize the polarizing blue blocking lens.

The typical situation for the pilot is as follows: The time is noon, with the sun at zenith. The pilot is a highly variable distance from cloud cover which can change on short notice from overcast to brilliant sun. The state of polarization can also change dramatically depending upon  
25 the direction of the sun and the cloud conditions. For these reasons it is difficult to predict the hazard the pilot is exposed to. However, it is known that the pilot is exposed to far more intensity of overall blue and UV due to the altitude. (Atmosphere absorbs UV and blue light to some extent so persons at high altitude are at greater risk than those close to sea level.)  
30 A pilot may use any cut-on lens from 515 to 550 to mitigate the damage. The unexplained effect of this invention which allows them to be used over a wide range of light conditions will be of use to the pilot.

While the invention has been described in complete detail and pictorially shown in the accompanying drawings it is not to be limited to such details, since many changes and modification may be made to the



invention without departing from the spirit and the scope thereof. For example, the inventive lens 10 also has application in automobile and aircraft windshields, special application windows, flight, ski and welding goggles or visors, and in microscopes, telescopes or ophthalmoscopes.

5 Hence, it is described to cover any and all modifications and forms which may come within the language and scope of the claims.

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CLAIMS

1. A sunglass lens comprising:
  - a) means to substantially and selectively block wavelengths in the electromagnetic spectrum that are between 300 and 549 nanometers,
  - b) means to cut-on at a wavelength selected at specific intervals between 450 and 550 nanometers,
  - c) means to substantially transmit wavelengths in the visible portion of the electromagnetic spectrum that are longer than 625 nanometers, and
  - d) means to substantially block horizontally polarized light.
2. The sunglass lens as specified in claim 1 wherein said means to substantially block wavelengths between 300 and 449 nanometers, to cut-on at a selected wavelength of 450 nanometers, to transmit between 10 and 90 percent of the wavelengths longer than 625 nanometers and to substantially block horizontally polarized light, is accomplished by incorporating into said lens a polarized sharp cut-on filter that cuts-on at 450 nanometers.
3. The sunglass lens as specified in claim 1 wherein said means to substantially block wavelengths between 300 and 499 nanometers, to cut-on at a selected wavelength of 500 nanometers, to transmit between 10 and 90 percent of the wavelengths longer than 625 nanometers and to substantially block horizontally polarized light, is accomplished by incorporating into said lens a polarized sharp cut-on filter that cuts-on at 500 nanometers.
4. The sunglass lens as specified in claim 1 wherein said means to substantially block wavelengths between 300 and 514 nanometers, to cut-on at a selected wavelength of 515 nanometers, to transmit between 10 and 90 percent of the wavelengths longer than 625 nanometers and to substantially block horizontally polarized light, is accomplished by incorporating into said lens a polarized sharp cut-on filter that cuts-on at 515 nanometers.

5. The sunglass lens as specified in claim 1 wherein said means to substantially block wavelengths between 300 and 529 nanometers, to cut-on at a selected wavelength of 530 nanometers, to transmit between 10 and 90 percent of the wavelengths longer than 625 nanometers and to substantially block horizontally polarized light, is accomplished by incorporating into said lens a polarized sharp cut-on filter that cuts-on at 530 nanometers.
6. The sunglass lens as specified in claim 1 wherein said means to substantially block wavelengths between 300 and 549 nanometers, to cut-on at a selected wavelength of 550 nanometers, to transmit between 10 and 90 percent of the wavelengths longer than 625 nanometers and to substantially block horizontally polarized light, is accomplished by incorporating into said lens a polarized sharp cut-on filter that cuts-on at 550 nanometers.
7. The lens as specified in claim 2, 3, 4, 5, or 6, wherein said lens transmits between 30 and 40 percent of the wavelengths longer than 625 nanometers.
8. The lens as specified in claims 2, 3 or 4 wherein said sharp cut-on filter that cuts-on at 450, 500 or 515 nanometers is incorporated into said lens by applying to said lens a combination dye derived from a mixture of a yellow dye and an orange dye.
9. The lens as specified in claim 8 wherein said combination dye, that results in a cut-on at 450 nanometers, is applied to said lens by a hot-dip combination dispersed dye process that essentially consists of immersing said lens into a vessel containing a mixture of dispersed yellow twenty-three dye and dispersed orange three dye in a concentration ratio of approximately 1 to 1, for a period of 2.5 minutes at a temperature of  $98 \pm 1$  degree centigrade.
10. The lens as specified in claim 8 wherein said combination dye, that results in a cut-on at 500 nanometers, is applied to said lens by hot-dip combination dispersed dye process that essentially consists of immersing said lens into a vessel containing a mixture of dispersed yellow twenty-three dye and dispersed orange three

dye in a concentration ratio of approximately 1 to 1, for a period of 5.0 minutes at a temperature of  $98 \pm 1$  degree centigrade.

11. The lens as specified in claim 8 wherein said combination dye, that results in a cut-on at 515 nanometers, is applied to said lens by a hot-dip combination dispersed dye process that essentially consists of immersing said lens into a vessel containing a mixture of dispersed yellow twenty-three dye and dispersed orange three dye in a concentration ratio of approximately 1 to 1, for a period of 12.0 minutes at a temperature of  $98 \pm 1$  degree centigrade.
12. The lens as specified in claims 5 or 6 wherein said sharp cut-on filter that cuts-on at 530 or 550 nanometers is incorporated into said lens by applying to said lens a combination dye derived from a mixture of an orange dye and a red dye.
13. The lens as specified in claim 12 wherein said combination dye, that results in a cut-on at 530 nanometers, is applied to said lens by a hot-dip combination dispersed dye process that essentially consists of immersing said lens into a vessel containing a mixture of dispersed red two dye and dispersed orange three dye in a concentration ratio of approximately 1 to 1, for a period of 4.5 minutes at a temperature of  $98 \pm 1$  degree centigrade.
14. The lens as specified in claim 12 wherein said combination dye, that results in a cut-on at 550 nanometers, is applied to said lens by a hot-dip combination dispersed dye process that essentially consists of immersing said lens into a vessel containing a mixture of dispersed red two dye and dispersed orange three dye in a concentration ratio of approximately 1 to 1, for a period of 12.0 minutes at a temperature of  $98 \pm 1$  degree centigrade.
15. The lens as specified in claims 2, 3, 4 or 5 wherein said sharp cut-on filter that cuts-on at 450, 500, 515 or 530 nanometers is incorporated into said lens by applying to said lens a dye derived from either an orange or a yellow dye.
16. The lens as specified in claim 15 wherein said dye that results in a cut-on at 450 nanometers, is applied to said lens by a hot-dip dispersed dye process that essentially consists of immersing said lens into a vessel containing the yellow twenty-three dye for a

period of 16 minutes and at a temperature of  $98 \pm 1$  degree Centigrade.

17. The lens as specified in claim 15 wherein said dye that results in a cut-on at 500 nanometers, is applied to said lens by a hot-dip dispersed dye process that essentially consists of immersing said lens into a vessel containing the orange three dye for a period of 5 minutes and at a temperature of  $98 \pm 1$  degree centigrade.
18. The lens as specified in claim 15 wherein said dye that results in a cut-on at 515 nanometers, is applied to said lens by a hot-dip dispersed dye process that essentially consists of immersing said lens into a vessel containing the orange three dye for a period of 12 minutes and at a temperature of  $98 \pm 1$  degree centigrade.
19. The lens as specified in claim 15 wherein said dye that results in a cut-on at 530 nanometers, is applied to said lens by a hot-dip dispersed dye process that essentially consists of immersing said lens into a vessel containing the orange three dye for a period of 18 minutes and at a temperature of  $98 \pm 1$  degree centigrade.
20. The lens as specified in claim 1 wherein said means to block horizontally polarized light is accomplished by a horizontally polarizing filter that is applied to said lens by an application means.
21. The lens as specified in claim 20 wherein said polarizing filter application means is accomplished by laminating, molding or casting a polarizing film into said lens.
22. The lens as specified in claim 1 wherein said lens is made from optical plastic.
23. The lens as specified in claim 22 wherein said optical plastic is comprised of diallyl glycol carbonate.
24. The lens as specified in claim 1 wherein said lens is made from optical glass.
25. A family of sunglass lenses where each lens is comprised of a sharp cut-on filter having a variable blocking zone, a selectable transition zone, and a common transmissive zone, where the blocking zone selectively blocks wavelengths in the electromagnetic spectrum between 300 and 549 nanometers and

the transmissive zone allows between 30 and 40 percent of the wavelengths in the spectrum that are longer than 625 nanometers to be transmitted, where the blocking zone wavelength range is selectable and is determined by the selection of a specific sharp cut-on filter that is designed to cut-on at either 450, 500, 515, 530 or 550 nanometers and where said filter includes a horizontally polarizing film that substantially blocks horizontally polarized light.

26. A method for producing a sunglass lens that substantially and selectively blocks wavelengths between 300 and 549 nanometers, that cuts-on at a selected wavelength that falls at specific intervals between 450 and 550 nanometers, that transmits between 30 and 40 percent of the wavelengths in the visible portion of the electromagnetic spectrum that are longer than 625 nanometers and that substantially blocks horizontally polarized light where said method comprises the following steps:
- a) procure an optical plastic lens having a polarizing film embedded therein,
  - b) immerse said lens into a vessel having a combination dye that comprises two sharp cut-on dyes where each dye has an ultraviolet hole at a different wavelength that causes said UV hole to be eliminated and where the two dyes are selected as follows:
    - 1) for a sharp cut-on of 450 nanometers, use a hot-dip combination dispersed dye process that essentially consists of immersing said lens into a vessel containing a mixture of dispersed yellow twenty-three dye and dispersed orange three dye in a concentration ratio of 1 to 1, for a period of 2.5 minutes at a temperature of  $98 \pm 1$  degree centigrade,
    - 2) for a sharp cut-on of 500 nanometers, use a hot-dip combination dispersed dye process that essentially consists of immersing said lens into a vessel containing a mixture of dispersed yellow

twenty-three dye and dispersed orange three dye in a concentration ratio of 1 to 1, for a period of 5.0 minutes at a temperature of  $98 \pm 1$  degree centigrade,

3) for a sharp cut-on of 515 nanometers, use a hot-dip combination dispersed dye process that essentially consists of immersing said lens into a vessel containing a mixture of dispersed yellow twenty-three dye and dispersed orange three dye in a concentration ratio of 1 to 1, for a period of 12.0 minutes at a temperature of  $98 \pm 1$  degree centigrade,

4) for a sharp cut-on of 530 nanometers, use a hot-dip combination dispersed dye process that essentially consists of immersing said lens into a vessel containing a mixture of dispersed red two dye and dispersed orange three dye in a concentration ratio of 1 to 1, for a period of 4.5 minutes at a temperature of  $98 \pm 1$  degree centigrade,

5) for a sharp cut-on of 550 nanometers, use a hot-dip combination dispersed dye process that essentially consists of immersing said lens into a vessel containing a mixture of dispersed red two dye and dispersed orange three dye in a concentration ratio of 1 to 1, for a period of 12.0 minutes at a temperature of  $98 \pm 1$  degree centigrade,

c) remove said lens from vessel,

d) edge lens to fit frame, and

e) dry and clean said lens and mount a pair of said lenses on a sunglass frame.

27. The lens as specified in claim 26 wherein said lens may remain in the vessel containing said combination dye for a longer period at a temperature of  $37 \pm 1$  degree centigrade where the time period is 10 days.

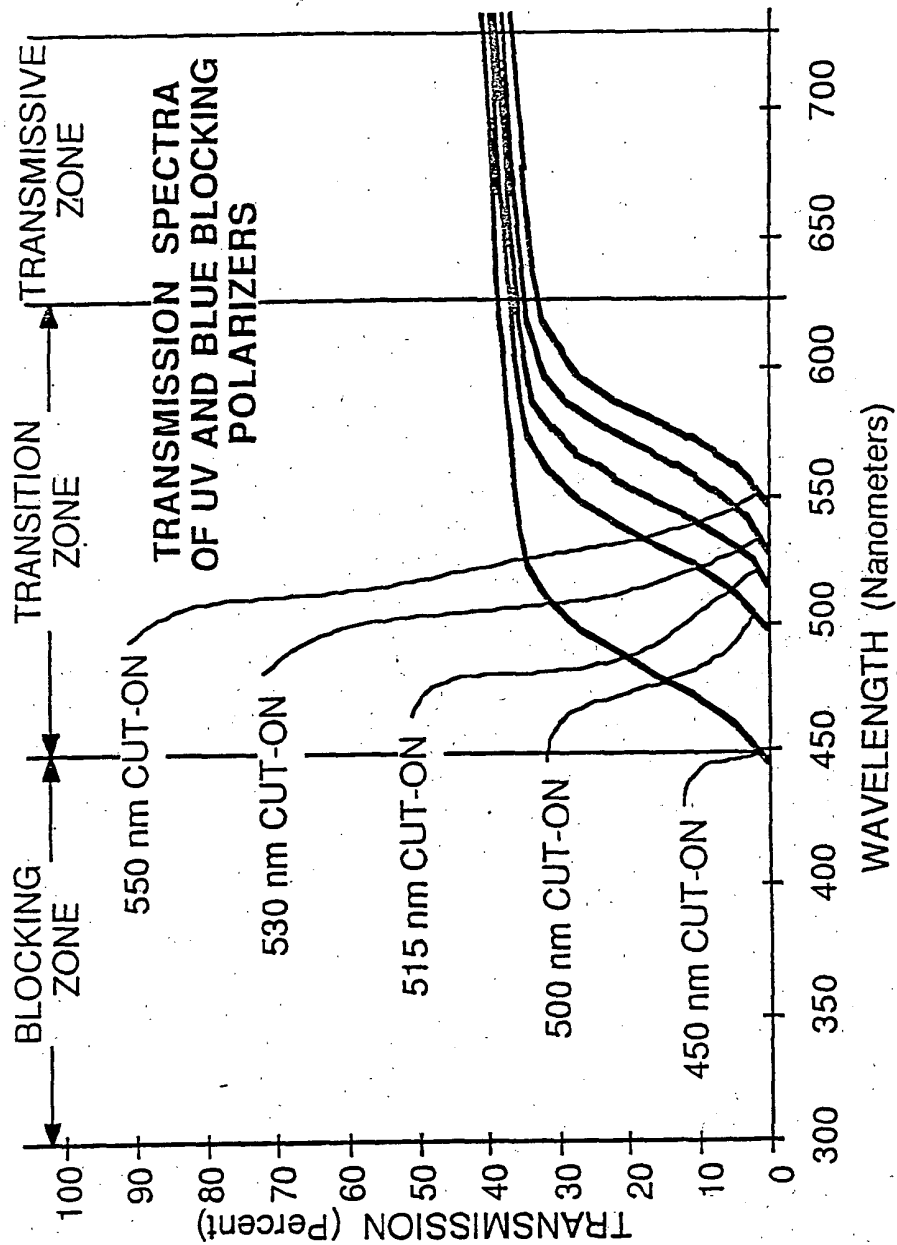


FIG. 1



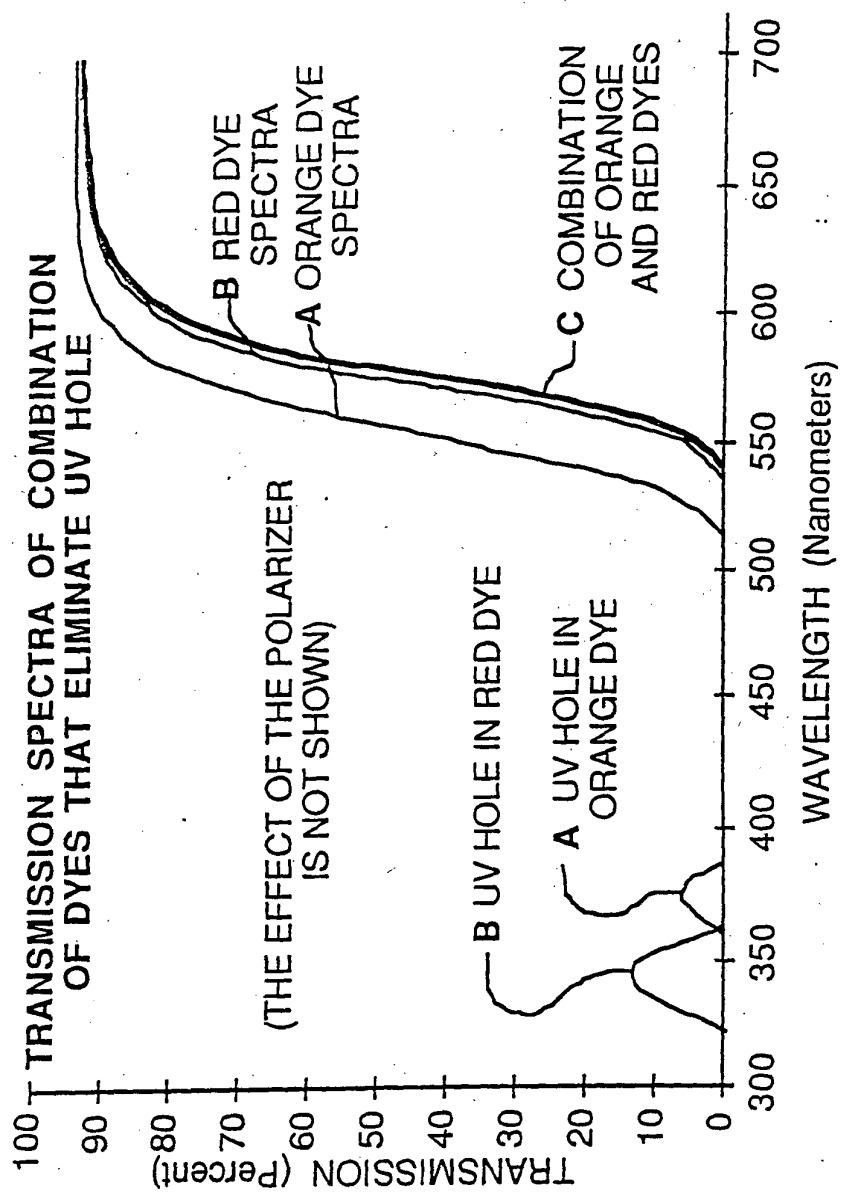


FIG. 2

WAVE LENGTH OF FILTER CUT-ON (nm.)	TIME IN COMBINATION DYE AT 98°C AND 0.25gm/liter CONCENTRATION			BEST MODE TABLE	
	SIDNEY SPRINGER DYE CO. LOS ANGELES, CA			RECOMMENDED USES	
	DISPERSED YELLOW 23	DISPERSED ORANGE 3	DISPERSED RED 2	ENVIRONMENTS	ACTIVITY
450	2.5 MINUTES			TRAFFIC	ACTIVITIES REQUIRING COLOR VERITY
500	5.0 MINUTES			AQUATIC	LIFE GUARD
515	12.0 MINUTES			TRAFFIC	BOATER
530	4.5 MINUTES			AQUATIC	DRIVING REQUIRING STOP LIGHT VERITY
550	12.0 MINUTES			AQUATIC	FISHING
515 to 550	AS INDICATED ABOVE			HIGH ALTITUDE	PILOT

FIG. 3

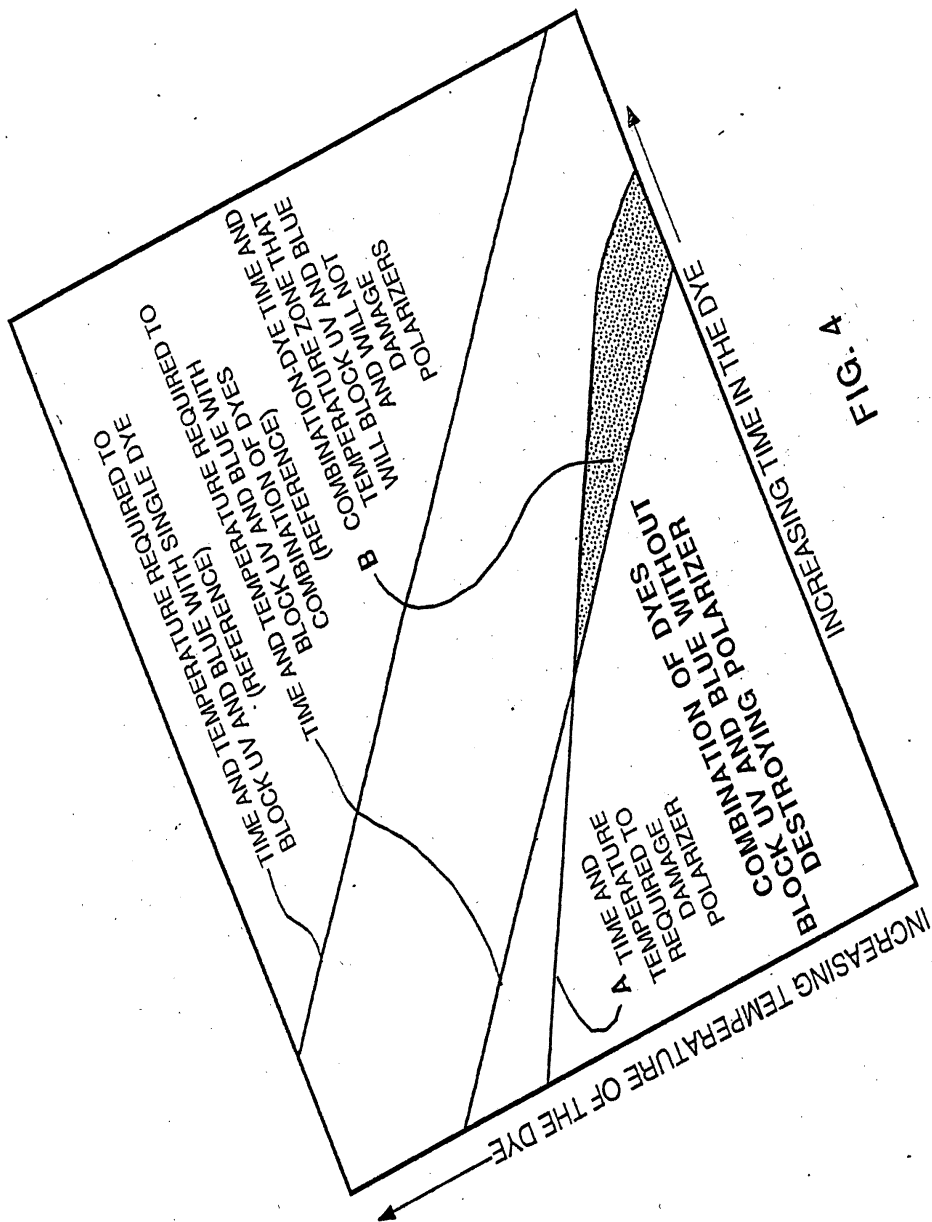


FIG. 4

# SUNGLASS MANUFACTURING PROCESSES

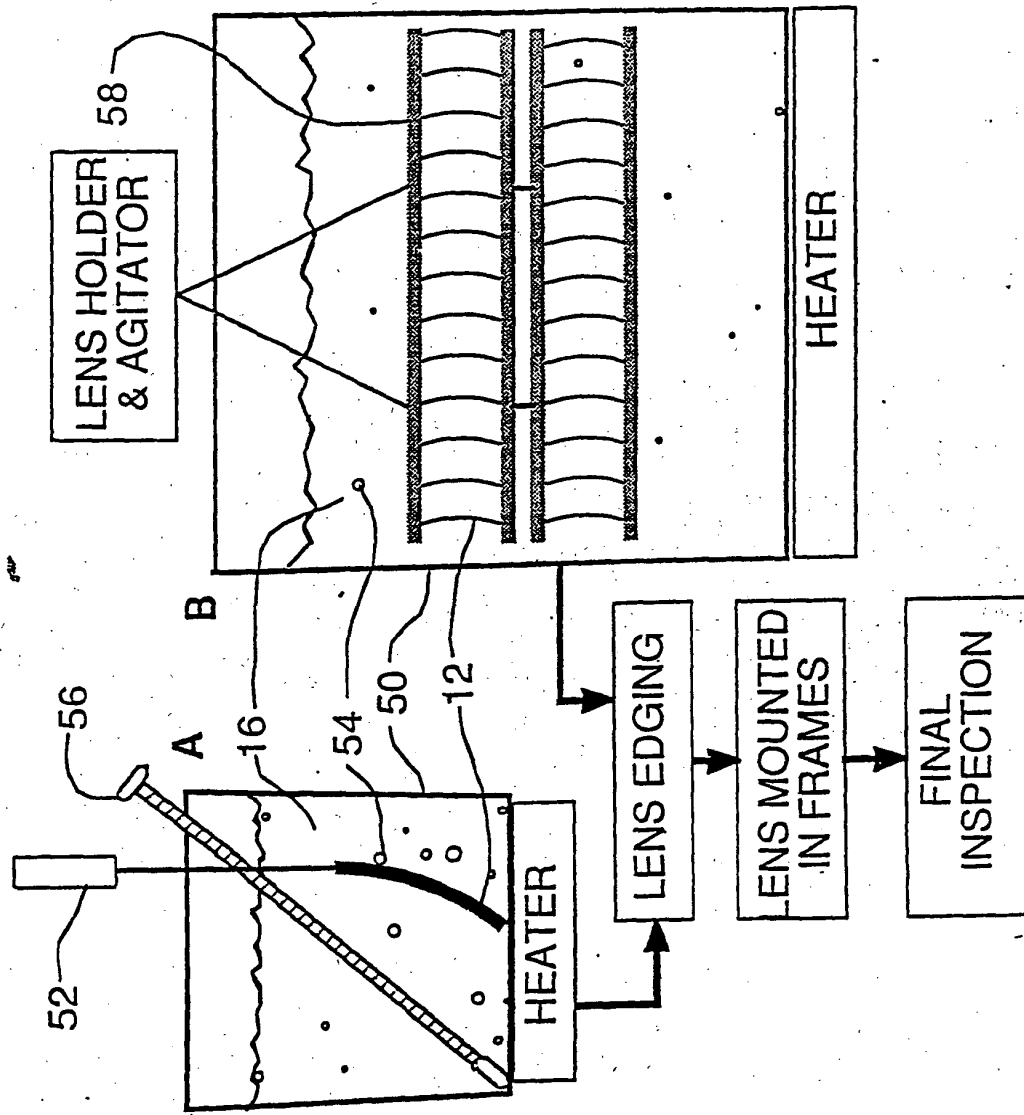


FIG. 5

# COMBINATIONS OF DYE LOCATION, LENS MATERIALS AND POLARIZER FILM

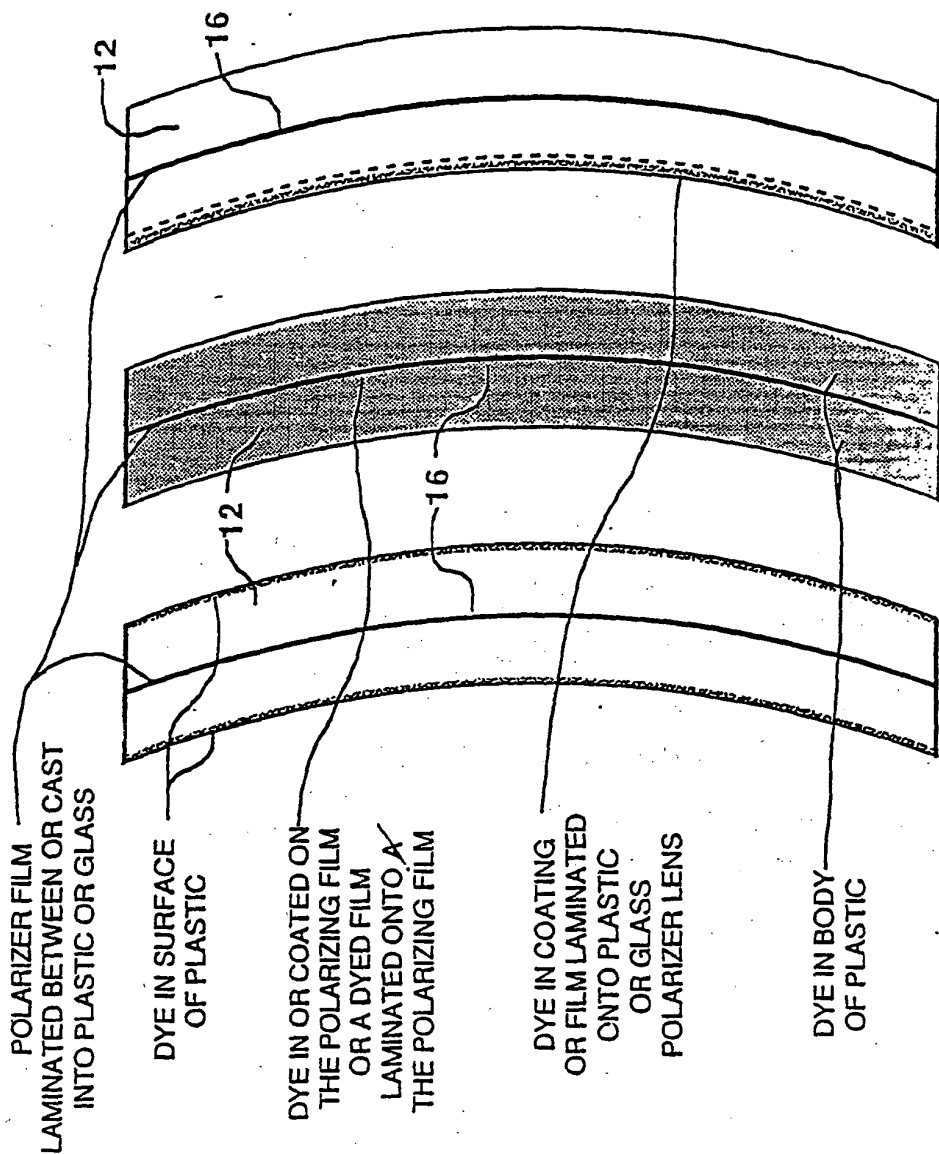


FIG. 8

FIG. 7

FIG. 6

POLARIZER FILM  
LAMINATED BETWEEN OR CAST  
INTO PLASTIC OR GLASS

DYE IN SURFACE  
OF PLASTIC

DYE IN OR COATED ON  
THE POLARIZING FILM  
OR A DYED FILM  
LAMINATED ONTO A  
THE POLARIZING FILM

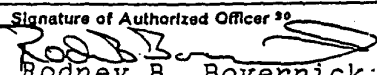
DYE IN COATING  
OR FILM LAMINATED  
ONTO PLASTIC  
OR GLASS  
POLARIZER LENS

DYE IN BODY  
OF PLASTIC

# INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 86/02213

<b>I. CLASSIFICATION OF SUBJECT MATTER</b> (If several classification symbols apply, indicate all) * According to International Patent Classification (IPC) or to both National Classification and IPC IPC(4): G02C 07/10, 09/00, 07/12 U.S. 351/44, 163						
<b>II. FIELDS SEARCHED</b> <div style="text-align: center; border-top: 1px solid black; border-bottom: 1px solid black; margin: 5px 0;">Minimum Documentation Searched *</div> <table style="width: 100%; border-collapse: collapse;"> <tr> <th style="width: 25%; border: 1px solid black; text-align: left;">Classification System</th> <th style="border: 1px solid black; text-align: left;">Classification Symbols</th> </tr> <tr> <td style="border: 1px solid black; padding: 5px;">U.S. CL:</td> <td style="border: 1px solid black; padding: 5px;">351/41, 44, 47, 48, 49, 163</td> </tr> </table> <div style="text-align: center; border-top: 1px solid black; border-bottom: 1px solid black; margin: 5px 0;">Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched *</div>			Classification System	Classification Symbols	U.S. CL:	351/41, 44, 47, 48, 49, 163
Classification System	Classification Symbols					
U.S. CL:	351/41, 44, 47, 48, 49, 163					
<b>III. DOCUMENTS CONSIDERED TO BE RELEVANT</b> **						
Category *	Citation of Document, ** with indication, where appropriate, of the relevant passages **	Relevant to Claim No. **				
A	N.W. Coblentz, "Spectral-Transmissive Properties and use of colored eye-protective Glasses", 01 June 1938, Published By U.S. Government Printing Office. See entire Document.	1-27				
A	US, A, 3,588,216 (BLOOM) 28 June 1971 See entire Document	1-27				
A	US, A, 2,370.697 (Tillyer) 06 March 1945 See entire Document	1-27				
A	The Optician, 05 June 1959, H. H. Emsley "Filters: Absorptive and Thin Film," See Pages 543-600	1-27				
<div style="display: flex; justify-content: space-between;"> <div style="width: 48%;"> <p>* Special categories of cited documents: **</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </div> <div style="width: 48%;"> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"A" document member of the same patent family</p> </div> </div>						
<b>IV. CERTIFICATION</b>						
Date of the Actual Completion of the International Search * <div style="text-align: center; font-size: 1.2em;">15 December 1986</div>		Date of Mailing of this International Search Report * <div style="text-align: center; font-size: 1.2em;">02 JAN 1987</div>				
International Searching Authority * <div style="text-align: center; font-size: 1.2em;">ISA/US</div>		Signature of Authorized Officer ** <div style="text-align: center;">               Rodney B. Bovernick         </div>				